THE UNIVERSITY OF YORK

EEEM

Department of Environmental Economics and Environmental Management

Discussion Papers in Environmental Economics and Environmental Management

Number 9307

A COST EFFECTIVE ENVIRONMENTALLY ADJUSTED PERFORMANCE INDICATOR

by

M. Common

Heslington, York, YO1 5DD
Telephone: 44 (0)904 432 999
Telefax: 44 (0)904 432 998

A COST EFFECTIVE ENVIRONMENTALLY ADJUSTED ECONOMIC PERFORMANCE INDICATOR

Mick Common
Environmental Economics and Environmental Management
University of York
and
Centre for Resource and Environmental Studies
Australian National University

Abstract

It is not possible to measure sustainable national income, and attempts to do so will consume non-trivial quantities of human and financial resources. There is a manifest desire for single number indicators of national economic performance adjusted for environmental impact. An approach is proposed which would exploit existing data sources, and which is, therefore, inexpensive. Results are reported which revise existing economic performance rankings.

A Cost Effective Environmentally Adjusted Economic Performance Indicator

M. Common
Department of Environmental Economics and Environmental Management, University of York, Heslington, York, YO1 5DD, UK.

1. Introduction

There is a widespread view that modifications to national income accounting procedures are crucial to the pursuit of sustainability. This view has been advanced by both economists and environmentalists. Thus, for example, Repetto *et al* (1989) claim, from the former perspective, that:

> A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife to extinction, but measured income would not be affected as these assets disappeared.

Here, "measured income" is GDP. According to Repetto *et al*

> politicians, journalists and even sophisticated economists in official agencies continue to use GDP growth as the prime measure of economic performance

and

> only if the basic measures of economic performance .....are brought into conformity with a valid definition of income will economic policies be influenced toward sustainability.

Similarly, from the latter perspective, *A Global Biodiversity Strategy* (World Resources Institute *et al* 1992) calls for national initiatives

> To adopt new public policies and accounting methods that promote conservation and the equitable use of biodiversity

citing as a means to these ends the modification of

> national income accounts to make them reflect the economic loss that results when biological resources are degraded and biodiversity is lost.

As indicated by these quotes, the sustainability problem, which revised national income accounting practice is intended to address, has its origins in the interconnections between economic activity and the natural environment. Production involves inputs drawn from the natural environment. Production and consumption give rise to wastes discharged into it.

Resource extraction and waste insertion are linked via the materials balance principle, otherwise the law of conservation of mass. The natural environment is also the base for a flow of amenity services to consumers. It also provides other services for production and consumption which are not easily categorised as input flows, and which are often referred to as life support functions. The four roles of the natural environment in relation to economic activity interact one with another in complex, and often poorly understood, ways. A number of conceptualisations of the economy-environment system have now appeared in the literature: see, for examples, Perrings (1987), Barbier (1989), Common and Perrings (1992), Common and Norton (1993).

Broadly, the sustainability problem can be said to that of managing current economic activity such that future human prospects are not reduced.[1] One source of threat to future human prospects is the impact of current economic activity on the natural environment. Another is an insufficiency of capital accumulation. The two are linked in so far as capital can substitute for environmental functions. In economics, features of the natural environment are treated as capital assets yielding a flow of services. The sustainability problem is then seen as the problem of finding the appropriate level and pattern of investment so as to maintain the total capital stock intact. Central to this problem, and to the measurement of sustainable national income is the problem of valuation. The notion of an aggregate capital stock, and of a flow of income arising, requires that prices exist. Further, if this notion is to serve the purpose required of it in the sustainability context, those prices must reflect the scarcities relevant to threats to sustainability.

In this paper it is argued, in section 3, that it is impossible to compute a measure of sustainable national income for any actual economy. Basically this is because the relevant scarcities are not, and cannot, be known. Section 2 of the paper discusses the several purposes for which the availability of data on the economy and the environment jointly might be seen as desirable. Section 4 proposes a very simple approach to producing environmentally adjusted economic performance data, which can serve *some* of these purposes at low cost. Some results are reported. Some concluding comments are offered in section 5.

2. The Purposes of Economy-Environment Data

The objectives for which economy-environment data might be generated and reported can be distinguished as follows:

1. The provision of historical records regarding human interactions with the environment.

2. The improvement of understanding of the relationships

between the state of the environment and its functioning in relation to human interests.

3. The improvement of human abilities to manage the environment in human interests.

4. The definition and measurement of performance indicators for economy-environment management.

5. The ability to make performance comparisons as between economies.

6. The provision of information for members of the public and participants in political processes.

These purposes are not, of course, mutually exclusive. The attainment of objective 3 would subsume objectives 1 and 2 in as much as improved management would require improved understanding based on historical data. While 1 is necessary for 2, and hence 3, it is not sufficient. Improved understanding involves analysis as well as data availability. While performance indicators could be based simply on historical data, in so far as they relate to performance in regard to human interests, their definition would presume progress in relation to objective 2. Similar considerations attach to objectives 5 and 6.

As noted above, with the emergence onto the public agenda of the sustainability problem, following publication of the Brundtland report in 1987 (World Commission on Environment and Development, 1987), there has been a renewed interest in the "proper" measurement of national income. In this context, "proper" means measurement that recognises the implications of economic activity for the natural environment and the feedbacks from such implications to economic activity. The call for such measurement is frequently put in terms of an extension of the Hicksian concept of income, Hicks (1946), as the maximum consumption in a period consistent with the maintenance of wealth intact: see, for example, Repetto *et al* (1989). Here such a measurement of national income will be called PNDP for Proper Net Domestic Product. The implication of much of the discussion of the desirability of PNDP data would appear to be that its availability would serve all of the purposes listed above.

It is, then, appropriate to consider a thought experiment in which PNDP data is actually available. Suppose that on 1st January of each year, God announces PNDP figures for every nation in the world for the year just ended. God does not announce anything else about economies or environments. There is no question but that the PNDP figures are accurate, allowing for resource depletion, pollution damage, biodiversity losses etc etc. What use would this information be in regard to the six objectives listed above? For each nation there would exist a PNDP time series. There would, objective 1, be historical records relating to human interactions with the environment. These would be acceptable to some as performance indicators, objective 4, in that for a given nation a downward movement would mean a lower future sustainable aggregate consumption level. Not everybody would regard PNDP as the only interesting performance indicator, of course. But, God would be making it possible to make international comparisons, objective 5, according to that performance indicator. And, there would be some information available for members of national publics and participants in the political process, objective 6.

God's information would not promote objectives 2 and 3. It would not, that is, improve human understanding of economy-environment relationships, and would not, therefore, improve human abilities to manage those relationships for human purposes. Given that God is providing only information, not management services, this is a fairly major problem. Unless, that is, one wishes to assume that human understanding is anyway sufficient for management purposes. Most would agree, it seems, that this is not a tenable assumption. Even among economists, there appear to be few who would wish to claim that everything can be left to the invisible hand, even after some extensions of private property rights. It should also be noted, perhaps, that if one did believe that everything could and should be left to market forces there would seem to be very little point in devoting resources to the production and publication of national income accounts of any kind.

While somewhat fanciful, this thought experiment provides a useful perspective on the claims often made, if only by implication, in regard to the need for and consequences which would follow from the availability of PNDP data. The point is not that PNDP data would be irrelevant to the pursuit of sustainability, but that the role of such data in and of itself would be rather limited. It would certainly not be sufficient, if necessary, for sustainability realisation. Abolishing God, the main contribution arising from PNDP data would derive from the construction of it, and the interaction between that activity and efforts to improve understanding of total system functioning, rather than from contemplation of and reaction to series of PNDP figures. Consideration of the history of the co-evolution of current national income measures with macroeconomics surely demonstrates this point. Keynesian demand management required a theoretical understanding, and associated empirical modelling, not merely the regular publication of GDP data. The theoretical understanding itself influenced the construction of the GDP data, and the empirical modelling generated demands for the publication of more disaggregated time series.

3. Accounting for Sustainable Income.

Mäler (1991), showed that PNDP as a measure of sustainable income can be defined and measured using the shadow prices that emerge from a dynamic optimisation problem.[2] He showed that a necessary condition for sustainability is that the value of the total capital stock, including environmental assets, be non-declining when aggregation uses the proper shadow prices. Mäler also related his PNDP measure, NWM in his terminology, to a standard accounting measure of NDP, and set out the adjustments necessary to go from the latter to the former.

A dynamic optimisation problem which is similar to that considered in Mäler(1991) is:

$$Max \sum_{0}^{\infty} U(X_t, L_{1t}, R_{3t}, R_{1t}) \rho^t : \quad \rho = (1+r)^{-1} \qquad (1)$$

subject to

$$R_{1t+1} = R_{1t} + G_1(R_{1t}, R_{2t}, R_{3t}) - Y_{1t}$$

$$Y_{1t} = F_1(L_{1t}, R_{1t})$$

$$R_{2t+1} = R_{2t} + G_2(R_{1t}, R_{2t}, R_{3t})$$

$$R_{3t+1} = R_{3t} + G_3(R_{3t}) + Y_{3t}$$

$$R_{4t+1} = R_{4t} - Y_{4t}$$

$$R_{5t+1} = R_{5t} + Y_{5t} - \delta R_{5t}$$

$$Y_{6t} = F_6(L_{6t}, R_{5t}, Y_{1t}, Y_{4t}, R_{3t}, Y_{7t}) \qquad (2)$$

$$Y_{7t} = h(Y_{4t})$$

$$Y_{3t} = Y_{7t} - Y_{8t}$$

$$Y_{8t} = F_8(L_{8t}, Y_{9t})$$

$$X_t = Y_{6t} - Y_{5t} - Y_{9t}$$

$$L_{1t} = L - L_{1t} - L_{6t} - L_{8t}$$

This extension of Mäler's model makes it possible to discuss biodiversity, which is a useful context in which to illustrate the essential argument here. R_1 and R_2 are interacting populations, both affected by the stock of pollution, R_3. R_1 is harvested, R_2 is not. The pollution stock decays by natural processes, $G_3(R_3)$, and is subject to net additions, Y_3, which are the difference between emissions, Y_7, and cleanup, Y_8. Emissions are a function of the use of the nonrenewable resource, R_4, in production. Cleanup activity uses labour, L_8, and produced output, Y_9. R_5 is man-made capital, used to produce output, Y_6. The other arguments in the production function are labour, L_6, the renewable resource harvest, Y_1, the extracted nonrenewable resource Y_4, the pollution stock, R_3, and emissions, Y_7. Output is allocated as between consumption, X, investment, Y_5, and cleanup activity, Y_9. Leisure, L_1, is the time invariant endowment of time, L, less its uses in harvesting the renewable resource, L_1, production, L_6, and cleaning up pollution, L_8.

This problem incorporates a purely instrumental concern for biodiversity, in as much as R_1 and R_2, their interrelationships, and the implications arising for human interests as represented in (1) are in the constraint set. Actually, this would be true even if R_1 did not appear as an argument in $U(\cdot)$. However, if the equation for R_2 did not appear in the constraint set, and the R_2 argument did not appear in $G_1(\cdot)$, then the problem would not pick up an instrumental concern for biodiversity. Economic models of economy-environment linkages frequently include only those natural resources which are themselves inputs to production, or feature as utility function arguments. To include in the problem formulation a non-instrumental concern for biodiversity, the utility function could be written as:

$$U_t = U(X_t, L_{1t}, R_{3t}, R_{1t}, R_{2t}) \qquad (3)$$

or

$$U_t = U(X_t, L_{1t}, R_{3t}, D\{R_{1t}, R_{2t}\}) \qquad (4)$$

where $D\{\cdot\}$ is some measure of biodiversity, such as that proposed by Weitzman (1991), for example, or as:

$$U_t = U(X_t, L_{1t}, R_{3t}, R_{1t}, R_{2t}, D\{R_{1t}, R_{2t}\}) \qquad (5)$$

where there is a concern for the absolute size of biotic populations as well as biodiversity.

It obviously cannot be claimed *a priori* that one of (3), (4) or (5) is right and the others wrong. However, each would imply, for a given specification of the constraint set (2), in terms of functional forms and parameter values, different shadow prices everywhere, a different specification of PNDP, and a different value for PNDP at t=0. PNDP measurement on this approach is, that is, model dependent. Unless, it is assumed that there can be consensus on the specification of the instantaneous utility function, or more generally an objective function, there is, even assuming that the constraint set specification is taken as given and correct, no prospect of a unique measure of PNDP. What this approach would measure is PNDP for a model, not PNDP for an actual economy. And, the nature of the adjustments to conventionally assessed NDP seen as required would also be model dependent.

In the formulation of the problem as the maximisation of a stationary utility function subject to a constraint set, it is generally understood that the utility function is that of some "representative" household. This might be considered a formulation of the sustainability problem that omits some of its key dimensions. One of these is widely understood to be intra-generational equity. Taking this on board would suggest an objective function in the nature of a social welfare function rather than a representative utility function, together with suitable extension and modification of the constraint set. While some such modification of the problem formulation is entirely feasible at the level of principle, it would not produce a PNDP measure as usually understood.[3] It can also be noted that in regard to either a utility function or a social welfare function, the assumption of stationarity is, in the context of the sustainability problem broadly conceived, itself restrictive.

Consider now the constraint set. Suppose first that (2) is "correct" in the sense that there are just two renewable resources, one pollution stock, etc etc. Then, the measure of PNDP will vary with the particular functional forms and parameter values used in a particular formulation of the model. Only if those used in modelling are the "correct" ones will measured PNDP be "correct" for some actual economy. Of course, (2), or some extended version thereof, is not going to be correct even in terms of general structural specification. In (2) itself there is an obvious "error" in that natural processes and/or cleanup activity make the pollutant vanish with no implications elsewhere in the system. The structural specification, that is, violates the law of conservation of mass. This is fairly typical in economic modelling. Generally, the point is that on this approach PNDP measurement is model dependent in regard to the constraint set, as well as in regard to the objective function. One of the few things we can be sure about is that we do not know the true model to use in this approach to PNDP measurement.

The point is that while a model can produce sustainability relevant valuations for the model, the relevance of those valuations to sustainability in an actual economy depends on the extent to which the model approximates to actuality. While PNDP measurement requires forward looking valuation, the relevant knowledge of future circumstances is inherently unavailable. This capital theoretic driven approach to PNDP measurement does make clear the nature of the measurement problem. However, since the "correct" way to specify the actual sustainability problem is unknown and unknowable, it produces PNDP measures for models rather than economies. These measures would of themselves be of very limited use in addressing actual sustainability problems.

The conclusion to be drawn from this is not that such modelling activities should be abandoned. On the contrary, they should be encouraged to develop as empirical, rather than purely analytical, exercises. However, such empirical exercises should not be seen as being for the purpose of producing PNDP numbers, or total asset value figures. Rather, the essential point should be seen as using constrained optimisation modelling to explore the implications of alternative formulations for objective functions and constraint sets, with a view to informing policy debate. It may be, for example, that some biota valuations emerging would be relatively insensitive to plausible variations in constraint set specification, while others would prove very sensitive. Such information could be of value in setting directions for scientific research. Again, some valuations might prove very sensitive to social welfare function variations, thus focussing political debate. Clearly, however, this is in the nature of a long term research agenda and the prospects for significant pay-offs in regard to management for sustainability lie well into the future.

Capital theorists are not the only economists contributing to the literature on PNDP measurement for sustainability. A more empirical and *ad hoc* interest in adjusting national income accounting data to reflect concerns which would now appear under the sustainability rubric actually pre-dates the widespread use of that terminology. US official data were adjusted in various ways by Nordhaus and Tobin (1972) and Zolotas (1981). Usher (1980) adjusted Canadian official data for resource depletion among other things and Pearce et al (1989) cite Japanese work on environmental adjustments dating from the early 70's. However, this work received major impetus with the emergence of widespread interest in sustainability.

This has been reflected in numerous publications and workshops. Official statistical agencies' activities (UNSO, IMF, OECD, World Bank, national government agencies) have thus far been restricted to discussions of proposals for construction of a PNDP measure, together with some physical data generation (eg. see Peskin with Lutz, 1990). PNDP type series have been constructed by some academic researchers; see Repetto *et al* (1989) for Indonesia, and Young (1990) for Australia, for examples. There are two basic, and closely related, problems with these proposals and measures, at the level of principle. First, they are atheoretical in that they lack any foundation in an explicitly articulated understanding of economy-environment interactions. Second, they are static in nature, whereas it is generally recognised, that the sustainability problem is inherently dynamic, as indicated in the above discussion of the capital theoretic analysis.

Two useful points of entry to the literature on proposals emanating from official agencies are Bartelmus *et al* (1989) and a "preliminary draft", on "General Concepts", for an *SNA Handbook on Integrated Environmental and Economic Accounting*, United Nations (1990). The former provides a fairly brief description of the basic strategy envisaged, which involves, in relation to existing SNA procedures, two new sets of accounts. In the first, which deals with flows of goods and services, flows relating to expenditures on environmental protection, "defensive expenditures", are separated out from all other flows to final demand. A measure of "Environmentally Adjusted GDP" is then derived by subtracting defensive expenditures from GDP:

(6) $EAGDP_t \equiv GDP_t - DE_t$

The second new set of accounts consists of opening and closing balance sheets for natural resources and environmental assets, together with two tables linking these in terms of physical and unit value changes over the period. "Environmental Cost" is defined as the difference between the value totals for the opening and closing balance sheets:

(7) $EC_t \equiv \sum v_{it}a_{it} - \sum v_{it-1}a_{it-1}$

Here a_i represents the size of the ith environmental asset and v_i the unit value assigned to that asset. Environmental cost is subtracted from Environmentally Adjusted GDP to give "Sustainable GDP":

(8) $SGDP_t \equiv EAGDP_t - EC_t$

Then, "Sustainable NDP", PNDP here, is derived by subtracting the depreciation of man-made capital stocks:

(9) $PNDP_t \equiv SGDP_t - D_t$

On this approach, the standard NDP measure is simply adjusted for defensive expenditures and the change in the value of the stock of environmental assets. This involves the assumptions that, environmental problems aside, NDP accounting conventions are satisfactory, and that the prices used therein are appropriate for sustainability. If these assumptions are granted and it is assumed that defensive expenditures can be properly identified and measured, attention can be directed to the problems arising at (7). Implementation of this approach requires there that all relevant environmental assets are identified and measured in physical terms, and that the appropriate valuations are applied to those physical measures. Clearly, major problems arise at each of the three stages here. In economics, the problem which receives most attention is that of valuation, given that many environmental assets readily identifiable as relevant are not valued in markets.

Environmental valuation is now a major research area in economics, and there is a substantial literature on theory and applications: see, for example, Blamey and Common (1993) for discussion and references. Broadly, there are two approaches. The first involves deriving missing prices from existing market prices. There are many variations on this theme, but if the results arising are to be regarded as sustainability relevant, all involve the assumption that existing market prices, or such corrected for market failure, are sustainability relevant. The second approach involves asking individuals for their valuations, and, as Contingent Valuation, is applied in the context of the amenity service function of the natural environment. This involves bringing the natural environment within the ambit of consumer demand theory. For both of these approaches to be used to measure PNDP the assumption must be that, given correction for market failure, market prices reflecting consumer sovereignty and efficiency are sustainability relevant. Both at the level of what is practicable and at the level of principle, there are good reasons to doubt this: see, for example, Common and Perrings (1992).

The practical question which arises is whether this pragmatic and *ad hoc* approach to a measure of PNDP is likely to promote the cause of sustainability. It is sometimes argued, in effect, that so long as the PNDP number is smaller than the NDP number that would otherwise have been produced, some useful purpose is served in regard to the objective, 6 in the listing in section 2 above, of influencing the public and decision makers. The useful purpose is taken to be moving policy in directions understood to promote sustainability. However, it is not necessarily the case that on all conceivable and practicable accounting conventions a PNDP number would be smaller than the corresponding NDP number. The problems of new discoveries and revaluations with regard to mineral deposits have received considerable attention in the literature. For Australia, Young (1990) computes a growth rate for his version of PNDP per capita which is more than twice that of GDP per capita for 1980-1988; some account is taken of habitat loss and land degradation, and defensive expenditures are netted out.

In terms of the objective of improving management of the economy-environment system, 3 in the listing in section 2 above, this may be promoted in so far as the effort to compute PNDP drives more extensive collection and systematic collation of physical data on environmental assets, which can be used in the study of economy-environment interconnections. However, in regard to the actual problems of understanding and management for sustainability this would be a very indirect way of addressing the problems of data availability. It is the physical data behind the monetary accounts that would be useful rather than the accounts themselves, that is. Such data could be used in the economy-environment modelling exercises described above.

In sum, the prospects for a PNDP measure that could do the job that its proponents require of it are very limited. Indeed, it could be argued that the pursuit of such a measure is counterproductive, in so far as it mis-represents the nature of the sustainability problem. It is not a problem that can be reduced to the dimensions of a single number indicator. It should also be noted that serious attempts to measure PNDP would require non-trivial resource inputs. In the next section of the paper a measure is discussed which serves some of the purposes distinguished in section 2 above, which requires relatively trivial resource inputs for its computation, and which does not purport to capture all of the dimensions of the sustainability problem.

4. Environmentally Adjusted Economic Performance Indicators

The UN's *Human Development Report 1992* (United Nations Development Programme, 1992), hereafter referred to as HDR, gives data, in Table 1, for 160 nations on:

> Real GDP per capita for 1989, measured in Purchasing Power Parity, PPP, $s, here denoted as Y.[4]
>
> Life expectancy at birth, in years, for 1990, here denoted as L.
>
> Adjusted real GDP, derived from Y as described below, and here denoted as Y_a.

It also gives, in Tables 23 and 44, data, for 132 nations, on:

> A Greenhouse Index. The gases included in this index are: carbon dioxide, methane and the chlorofluorocarbons. The index weights net emissions of each gas "according to its heat-trapping quality" and is expressed in metric tons of carbon per capita. This index is denoted here as G.

These are the data used in this paper. Note that as compared with measurement using official exchange rates, measurement of Y in PPP $s generally lowers measured Y for industrial economies and raises it for developing economies. For 1989, the HDR range for per capita real GNP is 80 to 29880 in $US at official exchange rates, while it is 557 to 23798 for per capita real CDP in PPP $s.

The primary objective of HDR is the computation of the Human Development Index, HDI, for 160 nations. The HDI is an index of relative performance, which takes account of income, longevity and a measure of educational attainment. The value of the index for the ith country is given by

$$HDI_i = 1 - [1/3(YD_i + LD_i + ED_i)]$$

where

$$YD_i = (Y_{a,max}-Y_i)/(Y_{a,max}-Y_{a,min})$$

$$LD_i = (L_{max}-L_i)/(L_{max}-L_{min})$$

$$Ed_i = (E_{max}-E_i)/(E_{max}-E_{min})$$

E an index of educational attainment. Each of YD_i, LD_i and ED_i are measures of the ith country's relative performance in terms of the highest and lowest scores. For each of the three sub-indices, the highest possible score is 0 and the lowest possible score is 1. Hence, when the sub-indices are entered into (1), the maximum possible HDI_i value is 1 for a country which was the maximum country on all three sub-indices, and the minimum possible HDI_i value would be 0 for a country which was the minimum country on all three sub-indices.

The per capita income measure used in the construction of the HDI, Y_a in the notation here, is constructed as follows. A poverty line in terms of PPP\$, Y_p, is calculated at \$4829, being "that income level below which a minimum nutritionally diet plus essential non-food requirements are not available" (p 208, United nations Development Programme, 1992). Then, adjusted income is, Y_a:

$$Y_{ai} = Y_i \qquad \text{for } Y_i \leq Y_p$$

$$Y_{ai} = Y_p+2(Y_i-Y_p)^{1/2} \qquad \text{for } Y_p<Y_i\leq 2Y_p$$

$$Y_{ai} = Y_p+2(Y_p)^{1/2}+3(Y_i-2Y_p)^{1/3} \qquad \text{for } 2Y_p<Y_i\leq 3Y_p$$

$$Y_{ai} = Y_p+2(Y_p)^{1/2}+3(Y_p)^{1/3}+4(Y_i-3Y_p)^{1/4} \qquad \text{for } 3Y_p<Y_i\leq 4Y_p$$

and so on. Up to the poverty line dollars of PPP\$ GDP get fully counted as dollars of adjusted income. Above the poverty line, extra PPP\$ GDP dollars are discounted at a rate which increases in steps as PPP\$ GDP gets further above the poverty line. The HDI incorporates a special form of diminishing utility of income.

Table 1 here gives the data to be used for the 132 nations for which G data are available, together with the HDI rank for each nation. These ranks are used as identifiers in the Tables and Figures to follow here. Note that the HDR classifies nations as belonging to high, medium and low human development categories.

A simple index of environmentally adjusted economic performance is YL/G, lifetime per capita GDP divided by per capita net greenhouse gas emissions. There are two reasons for using G in this way. First, the enhanced greenhouse effect is itself widely regarded as a major threat to sustainability. Second, G can be taken as a reasonable proxy for the sustainability relevant general environmental impact of economic activity.

Regarding the first point, Houghton *et al* (1992) provides an update of the 1990 scientific assessment of climate change prospects from the Intergovernmental Panel on Climate Change. This assessment is representative of majority scientific opinion: for a self-declared dissenting view see Balling (1992). According to Houghton *et al* (1992): "the sensitivity of global mean surface temperature" to an increase in greenhouse gas concentrations equivalent to a doubling of the pre-industrial carbon dioxide concentration "is unlikely to lie outside the range 1.5-4.5^{0}C" (p 5). The best available estimate of the rate of change of global mean surface temperature over the next century is taken to be "0.3^{0}C/decade (range 0.2 to 0.5^{0}C/decade)" (p 17).[5] By the standards of the last one million years, the earth appears currently to be in a relatively warm phase of its climatic history (see Figure 1 in Balling 1992, for example). It also appears that a rate of change of 0.3^{0}C/decade would be higher than has been experienced during the last 10,000 years, and high by longer term historical standards. Houghton *et al* emphasise the uncertainties attending climate change projections. The uncertainties are compounded when attempting to assess the impacts of prospective climate change. Nonetheless, Nordhaus (1991) has attempted to compare the costs and benefits of greenhouse gas emissions abatement, so as to determine the optimal level of abatement effort, and provides references to impact studies. Impact studies to date do not appear to have considered the implications of the rate of change.

The basis for taking G to proxy sustainability relevant impacts generally is, briefly, as follows. The major sources of carbon dioxide emissions are fossil fuel and biomass combustion, and land use changes, notably deforestation.[6] Fossil fuels and biomass are the major sources of extrasomatic energy. Their combustion releases many waste products, in addition to carbon dioxide, into the atmosphere. Energy use is necessary to shift and transform matter, which is largely what economic activity is about and is the source of its environmental impacts. Fossil fuels are exhaustible resources which cannot be recycled. Deforestation is a major source of biodiversity loss. The major sources for methane emissions are rice paddies, ruminant animals, fossil fuel extraction, and landfill waste disposal. Agriculture is a source of biodiversity loss. The chlorofluorocarbons are involved in the depletion of the stratospheric ozone layer, as well as being greenhouse gases. That depletion has direct implications for human health, and for photosynthetic primary production (especially in the oceans): see chapter five of Meadows *et al* (1992) for discussion and references.

Table 2 here gives, under I, the values for YL/G for 132 nations. The nations are ranked according to this index in Table 3. Figure 1 plots normalised values for I against Y, where the normalisation is I_i/I_{max}. Also shown in Figure 1 are the average normalised I for the world (equals 132 nations), and the means and standard deviations for the three HDR categories of nations. The top dozen nations, with HDR category and Y in parenthesis, on this index are:

48 Mauritius (medium, $5375)
105 Solomon Islands (low, $2626)
104 Cape Verde (low, $1717)
106 Morocco (low, $2298)
64 Fiji (medium, $4192)
38 Malta (high, $8231)
5 Sweden (high, $14817)
4 Switzerland (high, $18590)
36 Chile (high, $4987)
20 Barbados (high, $8351)
25 Cyprus (high, $9368)
124 Haiti (low, $962)

Canada ranks first according to HDI, 48th according to I. The nation with the highest Y included here is United Arab Emirates, which ranks 66th according to I.

A more general version of the index would be $Y^{\alpha}L^{\beta}/G^{\delta}$. For $0<\alpha<1$, $\beta=1$, $\delta=1$, for example, per capita GDP is subject to diminishing marginal utility. The index values for II reported in Figure 2 and Tables 2 and 3 are computed using $\alpha=0.8$, $\beta=1$ and $\delta=1$. As noted above, the HDI uses a special version of diminishing utility of income, captured in Y_a. The index III is Y_aL/G. On this basis, as shown in Figure 3, the mean of the normalised index is lower for the high human development category of nations than it is for the other two. The index IV is YL/G^2, to illustrate the effects of assuming that environmental impact is a non-linear function of the greenhouse index.

Looking at the Figures, the impression is that the general picture, in terms of the relative positions of the nations, is surprisingly stable across the index variations considered here. The rank correlation coefficients are:

HDI/I	0.54
Y/I	0.57
I/II	0.97
I/III	0.86
I/IV	0.88

5.Discussion

There is a widespread interest in environmentally adjusted economic performance indicators for nations. Particularly, there is interest in, and activity directed toward, the measurement of sustainable national income. Unfortunately, such measurement is impossible. Attempts to construct numbers for PNDP will involve considerable expense. The generation of the physical data necessary for such attempts may involve substantial benefits, as it will facilitate the empirical modelling of economy-environment interactions. It is not clear that the attempted production of PNDP numbers *per se* will involve any benefits. Given that such numbers would have no firm basis as measures of sustainable income, their publication could obscure rather than clarify issues relevant to the pursuit of sustainability.

The approach proposed here involves very little expense, and produces numbers which are relevant to the purposes 1, 4, 5 and 6 distinguished in section 2 above. Given the availability of the HDR data, the computations for the results reported took of the order of one manweek using a standard spreadsheet package, including data entry. Given the data in a spreadsheet, computation of alternative versions of the index is trivial. The can no doubt be legitimate questions raised about the accuracy of G as a measure of net greenhouse gas emissions. However, there is now in hand a great deal of scientific work on this measurement. The Climate Convention signed by over 150 nations at the June 1992 United Nations Conference on Environment and Development in Rio de Janeiro required all signatories to provide periodic updates on their greenhouse gas inventories of greenhouse gases by sources and sinks. Individual nations could readily produce, at very low cost, independent time series data for this type of index using their own sources instead of, or with, HDR sources. The Human Development Report is an annual publication. An alternative index, equally easily produced, could have per capita energy use as denominator. In so far as this would include energy sources in addition to fossil fuels and biomass, some might regard this as an improvement.

The most natural of the versions of the index considered here is I, which gives lifetime per capita income per unit G. The variations were considered in order to make it explicit that exploring the sensitivity of the basic index to variations that might be proposed is straightforward and inexpensive. It appears that in ranking terms the basic index is reasonably robust. The index does not purport to measure either sustainable income or economic welfare. It is intended simply as a cost effective response to the manifest desire for an environmentally adjusted economic performance indicator. It is not claimed that it is "the correct" indicator. On the contrary, one of its virtues is seen as the transparency of its weaknesses. While an increase in the value taken by the index for a nation from one year to the next would be suggestive of economic improvement taking account of environmental impact, nobody could be mislead into thinking that sustainable income, or economic welfare, had definitely increased. Given this, it is suggested that the temptation to introduce additional arguments, either in the numerator or the denominator, should probably be resisted.

There is what might be regarded as a weakness in the indicator which is perhaps not transparent. G refers to net emissions arising at a geographical location. It does not refer to emissions attributable to the consumption levels of the inhabitants of a nation.[7] An economy might have a structure such that low G exports are exchanged for high G imports, or vice versa. Clearly, an exactly analogous problem would attend PNDP data to the extent that the prices used for its computation did not properly reflect sustainability relevant environmental impacts wherever in the world they occurred.

Table 1 Data for EAEPI

	Real GDP per capita (PPP$) 1989	Adjusted real GDP	Life expectancy at birth (years) 1990	Greenhouse index (carbon heating equivalents in metric tons per capita (1988-89)
High human development				
1 Canada	18,635	5,051	77.0	4.9
2 Japan	14,311	5,018	78.6	2.3
3 Norway	16 838	5,047	77.1	3.0
4 Switzerland	18,590	5,051	77.4	2.4
5 Sweden	14,817	5,036	77.4	1.9
6 USA	20,998	5,074	75.9	5.3
7 Australia	15,266	5,040	76.5	5.2
8 France	14,164	5,018	76.4	2.4
9 Netherlands	13,351	5,014	77.2	3.0
10 United Kingdom	13,732	5,016	75.7	3.2
11 Iceland	14,210	5,018	77.8	2.4
12 Germany	14,507	5,027	75.2	3.7
13 Denmark	13,751	5,016	75.8	3.4
14 Finland	14,598	5,032	75.5	3.0
15 Austria	13,063	5,013	74.8	2.3
16 Belgium	13,313	5,014	75.2	3.1
17 New Zealand	11,155	5,002	75.2	3.7
18 Israel	10,448	4,996	75.9	2.3
19 Luxembourg	16,537	5,046	74.9	5.7
20 Barbados	8,351	4,948	75.1	1.1
21 Italy	13,608	5,015	76.0	2.4
22 Ireland	7,481	4,932	74.6	3.2
23 Spain	8,723	4,954	77.0	2.2
25 Cyprus	9,368	4,964	76.2	1.3
26 Greece	6,764	4,917	76.1	2.5
27 Czechoslovakia*	7,420	4,931	71.8	3.3
28 Hungary	6,245	4,904	70.9	1.8
29 Uruguay	5,805	4,891	72.2	1.2
30 Trinidad and Tobago	6,266	4,905	71.6	3.1
32 Poland	4,770	4,770	71.8	2.9
33 USSR*	6,270	4,905	70.6	3.4
34 Korea, Rep. of	6,117	4,901	70.1	1.2
35 Bulgaria*	5,064	4,860	72.6	3.0
36 Chile	4,987	4,854	71.8	0.6
37 Yugoslavia	5,095	4,862	72.6	1.4
38 Malta	8,231	4,946	73.4	1.0
39 Portugal	6,259	4,905	74.0	1.8
40 Singapore	15,108	5,039	74.0	4.2
42 Costa Rica	4,413	4,413	74.9	4.1
43 Argentina	4,310	4,310	71.0	1.4
44 Venezuela	5,908	4,895	70.0	1.9
45 Kuwait	15,984	5,044	73.4	4.3
46 Mexico	5,691	4,888	69.7	1.5
Medium human development				
48 Mauritius	5,375	4,876	69.6	0.2
49 Albania*	4,270	4,270	72.2	0.8

51	Malaysia	5,649	4,886	70.1	3.2
55	Colombia	4,068	4,068	68.8	2.9
57	United Arab Emirates	23,798	5,079	70.5	7.9
59	Brazil	4,951	4,851	65.6	3.0
60	Romania*	3,000	3,000	70.8	2.2
61	Cuba*	2,500	2,500	75.4	0.9
62	Panama	3,231	3,231	72.4	2.1
63	Jamaica	2,787	2,787	73.1	0.6
64	Fiji	4,192	4,192	64.8	0.4
67	Saudi Arabia	10,330	4,994	64.5	2.7
69	Thailand	3,569	3,569	66.1	1.8
70	South Africa	4,958	4,852	61.7	2.2
71	Turkey	4,002	4,002	65.1	0.6
72	Syrian Arab Rep.	4,348	4,348	66.1	0.6
74	Libyan Arab Jamahiriya*	7,250	4,927	61.8	1.5
75	Korea, Dem.Rep.of*	2,172	2,172	70.4	1.6
76	Sri Lanka	2,253	2,253	70.9	0.5
77	Ecuador	3,012	3,012	66.0	3.5
78	Paraguay	2,742	2,742	67.1	3.3
79	China	2,656	2,656	70.1	0.6
80	Philippines	2,269	2,269	64.2	0.9
81	Peru	2,731	2,731	63.0	1.7
83	Dominican Rep.	2,537	2,537	66.7	0.4
85	Iraq*	3,510	3,510	65.0	0.9
86	Jordan	2,415	2,415	66.9	0.5
87	Tunisia	3,329	3,329	66.7	0.5
88	Mongolia*	2,000	2,000	62.5	1.5
89	Lebanon*	2,250	2,250	66.1	0.6
90	Iran, Islamic Rep. of	3,120	3,120	66.2	0.8
91	Gabon	4,735	4,735	52.5	2.5
92	Guyana	1,453	1.453	64.2	0.6
94	Botswana	3,180	3,180	59.8	1.1
95	Algeria	3,088	3,088	65.1	0.8
Low human development					
96	El Salvador	1,897	1,897	64.4	0.3
97	Nicaragua	1,463	1,463	64.8	3.4
98	Indonesia	2,034	2,034	61.5	1.3
100	Guatemala	2,531	2,531	63.4	1.1
101	Honduras	1,504	1,504	64.9	1.9
102	Viet Nam*	1,000	1,000	62.7	0.8
103	Swaziland	2,405	2,405	56.8	0.3
104	Cape Verde	1,717	1,717	67.0	0.1
105	Solomon Islands	2,626	2,626	69.5	0.1
106	Morocco	2,298	2,298	62.0	0.2
108	Zimbabwe	1,469	1,469	59.6	0.9
109	Bolivia	1,531	1,531	54.5	1.4
110	Egypt	1,934	1,934	60.3	0.5
111	Myanmar	595	595	61.3	4.3
113	Congo	2,382	2,384	53.7	1.6
114	Kenya	1,023	1,023	59.7	0.3
115	Madagascar	690	690	54.5	2.4
116	Papua New Guinea	1,834	1,834	54.9	0.6
117	Zambia	767	767	54.4	0.8
118	Cameroon	1,699	1,699	53.7	1.2
119	Ghana	1,005	1,005	55.0	0.6
120	Pakistan	1,789	1,789	57.7	0.2

121	India	910	910	59.1	0.5
123	Côte d'Ivoire	1,381	1,381	53.4	5.7
124	Haiti	962	962	55.7	0.1
125	Comoros	732	732	55.0	0.1
126	Tanzania, U.Rep. of	557	557	54.0	0.3
127	Zaire	380	380	53.0	1.4
128	Nigeria	1,160	1,160	51.5	0.8
130	Yemen*	1,560	1,560	51.5	0.2
131	Liberia	937	937	54.2	3.3
132	Togo	752	752	54.0	0.2
133	Uganda	499	499	52.0	0.2
134	Rwanda	680	680	49.5	0.1
135	Bangladesh	820	820	51.8	0.3
137	Senegal	1,208	1,208	48.3	0.3
138	Ethiopia	392	392	45.5	0.3
139	Angola	1,225	1,225	45.5	0.9
140	Nepal	896	896	52.2	0.7
141	Malawi	620	620	48.1	1.4
142	Burundi	611	611	48.5	0.1
144	Central African Rep.	770	770	49.5	1.0
145	Sudan	1,042	1,042	50.8	1.1
148	Mauritania	1,092	1,092	47.0	0.6
149	Benin	1,030	1,030	47.0	0.5
150	Chad	582	582	46.5	0.8
151	Somalia	861	861	46.1	0.8
154	Gambia	886	886	44.0	0.2
155	Mali	576	576	45.0	0.4
156	Niger	634	634	45.5	0.3
157	Burkina Faso	617	617	48.2	0.5
158	Afghanistan	710	710	42.5	0.2
159	Sierra Leone	1,061	1,061	42.0	0.4
160	Guinea	602	602	43.5	1.3

*** Real GDP figures are UNDP estimates**

Table 2. EAEPI Listings for 132 Nations

HDI Rank	I	II	III	IV
1	2928.4	409.8	793.7	1322.9
2	4890.6	721.5	1714.9	3224.8
3	4327.4	618.0	1297.1	2498.4
4	5995.3	839.4	1629.0	3869.9
5	6036.0	884.3	2051.5	4379.0
6	3007.1	410.9	726.6	1306.2
7	2245.9	327.1	741.5	984.9
8	4508.9	666.6	1597.4	2910.5
9	3435.7	513.9	1290.3	1983.6
10	3248.5	483.2	1186.6	1816.0
11	4606.4	680.5	1626.7	2973.4
12	2948.5	433.8	1021.7	1532.8
13	3065.7	455.9	1118.3	1662.6
14	3673.8	539.8	1266.4	2121.1
15	4248.3	638.3	1630.3	2801.3
16	3229.5	483.4	1216.3	1834.2
17	2267.2	351.6	1016.6	1178.7
18	3447.8	541.7	1648.7	2273.4
19	2173.0	311.4	663.1	910.2
20	5701.5	936.8	3378.1	5436.1
21	4309.2	642.2	1588.1	2781.6
22	1744.0	292.9	1149.8	974.9
23	3053.1	497.3	1733.9	2058.4
25	5491.1	881.7	2909.7	4816.0
26	2059.0	352.9	1496.7	1302.2
27	1614.4	271.6	1072.9	888.7
28	2459.8	428.4	1931.6	1833.5
29	3492.7	617.2	2942.8	3188.4
30	1447.2	251.9	1132.9	8221.0
32	1181.0	217.0	1181.0	693.5
33	1302.0	226.5	1018.5	706.1
34	3573.4	624.8	2863.0	3262.0
35	1225.5	222.5	1176.1	707.5
36	5967.8	1087.0	5808.6	7704.4
37	2642.1	479.2	2521.3	2233.0
38	6041.6	995.5	3630.4	6041.6
39	2573.1	447.9	2016.5	1917.9
40	2661.9	388.5	887.8	1298.9
42	806.2	150.5	806.2	398.1
43	2185.8	409.9	2185.8	1847.3
44	2176.6	383.3	1803.4	1579.1
45	2728.4	393.7	861.0	1315.8
46	2644.4	469.1	2271.3	2159.2
48	18705.0	3356.5	16968.5	41825.7
49	3853.7	724.1	3853.7	4308.5
51	1237.5	219.9	1070.3	691.8
55	965.1	183.1	965.1	566.7
57	2123.8	283.0	453.3	755.6
59	1082.6	197.5	1060.8	625.1
60	965.5	194.7	965.5	650.9
61	2094.4	438.0	2094.4	2207.7
62	1113.9	221.3	1113.9	768.7
63	3395.5	694.8	3395.5	4383.6
64	6791.0	1280.7	6791.0	10737.6
67	2467.7	388.6	1193.0	1501.8
69	1310.6	255.3	1310.6	976.9
70	1390.5	253.6	1360.8	937.5
71	4342.2	826.5	4342.2	5605.7
72	4790.1	896.8	4790.1	6183.9
74	2987.0	504.9	2029.9	2438.9
75	955.7	205.6	955.7	755.5
76	3194.8	682.2	3194.8	4518.1
77	568.0	114.4	568.0	303.6
78	557.5	114.5	557.5	306.9
79	3103.1	641.1	3103.1	4006.1
80	1618.6	345.1	1618.6	1706.1

81	1012.1	208.0	1012.1	776.2
83	4230.5	882.1	4230.5	6688.9
85	2535.0	495.4	2535.0	2672.1
86	3231.3	680.4	3231.3	4569.7
87	4440.9	877.0	4440.9	6280.4
88	833.3	182.2	833.3	680.4
89	2478.8	529.4	2478.8	3200.1
90	2581.8	516.5	2581.8	2886.5
91	994.4	183.0	994.4	628.9
92	1554.7	362.4	1554.7	2007.1
94	1728.8	344.6	1728.8	1648.3
95	2512.9	503.8	2512.9	2809.5
96	4072.2	900.0	4072.2	7434.8
97	278.8	64.9	278.8	151.2
98	962.2	209.7	962.2	843.9
100	1458.8	304.3	1458.8	1390.9
101	513.7	118.9	513.7	372.7
102	783.8	196.9	783.8	876.3
103	4553.5	959.7	4553.5	8313.5
104	11503.9	2593.5	11503.9	36378.5
105	18250.7	3779.4	18250.7	57713.8
106	7123.8	1515.1	7123.8	15929.3
108	972.8	226.3	972.8	1025.4
109	596.0	137.5	596.0	503.7
110	2332.4	513.5	2332.4	3298.5
111	84.8	23.6	84.8	40.9
113	799.5	168.8	799.5	632.0
114	2035.8	509.0	2035.8	3716.8
115	156.7	42.4	156.7	101.1
116	1678.1	373.4	1678.1	2166.4
117	521.6	138.2	521.6	583.1
118	760.3	171.8	760.3	694.1
119	921.3	231.2	921.3	1189.3
120	5161.3	1154.1	5161.3	11540.9
121	1075.6	275.3	1075.6	1521.2
123	129.4	30.5	129.4	54.2
124	5358.3	1356.4	5358.3	16944.6
125	4026.0	1076.4	4026.0	12731.3
126	1002.6	283.1	1002.6	1830.5
127	143.9	43.9	143.9	121.6
128	746.8	182.1	746.8	834.9
130	4017.8	923.2	4017.8	8982.3
131	153.9	39.2	153.9	84.7
132	2030.4	539.9	2030.4	4540.1
133	1297.4	374.5	1297.4	2901.1
134	3366.0	913.3	3366.0	10644.2
135	1415.9	370.1	1415.9	2585.0
137	972.4	235.2	972.4	1255.4
138	594.5	180.1	594.5	1085.5
139	619.3	149.4	619.3	652.8
140	668.2	171.6	668.2	798.6
141	213.0	58.9	213.0	180.0
142	2963.4	821.4	2963.4	9370.9
144	381.2	100.9	381.2	381.2
145	481.2	119.9	481.2	458.8
148	855.4	211.1	855.4	1104.3
149	968.2	241.8	968.2	1369.2
150	338.3	94.7	338.3	378.2
151	496.2	128.4	496.2	554.7
154	1949.2	501.6	1949.2	4358.5
155	648.0	181.8	648.0	1024.6
156	961.6	264.6	961.6	1755.6
157	594.8	164.6	594.8	841.2
158	1508.8	405.9	1508.8	3373.7
159	1114.1	276.5	1114.1	1761.5
160	23.2	6.4	23.2	6.9

Table 3. EAEPI Rankings

Rank	I	II	III	IV
1	48	105	105	105
2	105	48	48	48
3	104	104	104	104
4	106	106	106	124
5	64	124	64	106
6	38	64	36	125
7	5	120	124	120
8	4	36	120	64
9	36	125	72	134
10	20	38	103	142
11	25	103	87	130
12	124	20	71	103
13	120	130	83	36
14	2	134	96	96
15	72	96	125	83
16	11	72	130	87
17	103	5	49	72
18	8	83	38	38
19	87	25	63	71
20	71	87	20	20
21	3	4	134	25
22	21	71	86	86
23	15	142	76	132
24	83	49	79	76
25	96	2	142	63
26	125	63	29	5
27	130	76	25	154
28	49	11	34	49
29	14	86	90	79
30	34	8	85	4
31	29	21	37	114
32	18	7	95	158
33	9	5	89	110
34	63	34	110	34
35	134	3	46	2
36	10	29	43	89
37	86	18	61	29
38	16	132	5	11
39	76	14	114	8
40	79	89	132	133
41	13	90	74	90
42	23	9	39	95
43	6	110	154	15
44	74	114	28	21
45	142	74	44	85
46	12	95	23	135
47	1	154	94	3
48	45	23	2	74
49	40	85	116	18
50	46	16	18	37
51	37	10	15	61
52	90	37	4	116
53	39	46	11	46
54	85	13	80	14
55	95	39	8	23
56	89	61	21	92
57	67	12	92	9
58	28	28	158	39
59	110	6	26	43
60	17	43	100	16
61	7	1	135	28
62	43	158	70	126
63	44	45	69	10
64	19	67	133	159
65	57	40	3	156
66	61	44	9	80

67	26	133	14	13
68	114	116	16	94
69	132	135	67	44
70	154	92	10	12
71	22	26	32	121
72	94	17	35	67
73	116	80	22	100
74	80	94	30	149
75	27	7	13	1
76	92	19	159	45
77	158	100	62	6
78	100	22	121	26
79	30	126	27	40
80	135	57	51	137
81	70	159	59	119
82	69	121	12	17
83	33	27	33	148
84	133	156	17	138
85	51	69	81	108
86	35	70	126	155
87	32	30	91	7
88	159	149	108	69
89	62	137	137	22
90	59	119	149	70
91	121	33	60	19
92	81	108	55	27
93	126	35	98	102
94	91	62	156	98
95	108	51	75	157
96	137	32	119	128
97	149	148	40	30
98	60	98	45	140
99	55	81	148	81
100	98	75	88	62
101	156	59	42	57
102	75	102	113	75
103	119	60	1	35
104	148	55	102	33
105	88	91	118	118
106	42	88	128	32
107	113	128	7	51
108	102	155	6	88
109	118	138	140	139
110	128	118	19	60
111	140	140	155	113
112	155	113	139	91
113	139	157	109	59
114	109	42	157	117
115	157	139	138	55
116	138	117	77	151
117	77	109	78	109
118	78	151	117	145
119	117	145	101	42
120	101	101	151	144
121	151	78	145	150
122	145	77	57	101
123	144	144	144	78
124	150	150	150	77
125	97	97	97	141
126	141	141	141	97
127	115	127	115	127
128	131	115	131	115
129	127	131	127	131
130	123	123	123	123
131	111	111	111	111
132	160	160	160	160

References

Balling Jnr, R. C. 1992. *The Heated Debate: Greenhouse Prediction Versus Climate Reality*. San Francisco: Pacific Research Institute for Public Policy.

Barbier, E. B. 1989. *Economics Natural Resource Scarcity and Development: Conventional and Alternative Views*. London: Earthscan.

Bartelmus, P., Stahmer, C. and Van Tongeren, J. 1989. Integrated Environmental and Economic Accounting. Paper to *21st General Conference of the International Association for Research in Income and Wealth*, Lahnstein, August 1989.

Blamey, R. and Common, M. 1993. Sustainability and the Limits to Pseudo Market Valuation. In van den Bergh, C. J. M., and van der Straaten, J. (eds) *Concepts Methods and Policy for Sustainable Development: Critiques and New Approaches*. Island Press forthcoming.

Common, M. 1991. Natural Resource Accounting and Sustainability. *The Economic and Labour Relations Review* **2**: 89-121.

Common, M. and Perrings, C. 1992. Towards an Ecological Economics of Sustainability. *Ecological Economics* **6**: 7-34.

Common, M. and Norton, T. W. 1993. Biodiversity Natural Resource Accounting and Ecological Monitoring. Working Paper 1993/1, Centre for Resource and Environmental Studies, Australian National University.

Common, M. and Salma, U. 1992. Accounting for Australian Carbon Dioxide Emissions. *The Economic Record* **68**: 31-42.

Daly, H. E. and Cobb, J. B. 1989. *For the Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future*. Boston: Beacon.

Faber, M. and Proops, J. 1991. National Accounting, Time and the Environment. In Costanza, R. (ed) *Ecological Economics: The Science and Management of Sustainability*. New York: Columbia University Press.

Hartwick, J. 1990. National Accounting and the Wasting of Natural Resource Stocks. Mimeo, Queens University, Toronto.

Hicks, J. R. 1946. *Value and Capital: An Inquiry into some Fundamental Principles of Economic Theory*. Oxford: Oxford University Press.

Houghton, J. T., Callander, B. A. and Varney, S. K. (eds). 1992. *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*. Cambridge: Cambridge University Press.

Kravis, I. B., Kenessay, Z., Heston, A., and Summers, R. 1975. *A System of International Comparisons of Gross Product and Purchasing Power*. Baltimore: The Johns Hopkins University Press.

Mäler, K-G. 1991. National Accounts and Environmental Resources. *Environmental and Resource Economics* **1**: 1-15.

Meadows, D. H., Meadows, D. L. and Randers, J. 1992. *Beyond The Limits: Global Collapse or a Sustainable Future?* London: Earthscan.

Nordhaus, W. 1991. To Slow or Not to Slow: The Economics of the Greenhouse Effect. *Economic Journal* **101**: 920-937.

Nordhaus, W. and Tobin, J. 1972. Is Growth Obsolete? In *Economic Growth*. National Bureau of Economic Research General Series, Number 96E.

Parker, J. and Hope, C. 1992. The State of the Environment: A Survey of Reports from Around the World. *Environment* **34**: 19-21 and 39-44.

Pearce, D. W., Markandya, A. and Barbier, E. B. 1989. *Blueprint for a Green Economy*. London: Earthscan.

Perrings, C. 1987. *Economy and Environment: A Theoretical Essay on the Interdependence of Economic and Environmental Systems*. Cambridge: Cambridge University Press.

Peskin, H. M. with Lutz, E. 1990. *A Survey of Resource and Environmental Accounting in Industrialised Countries*. Environmental Working Paper 37. Washington D.C.: World Bank.

Repetto, R., Magrath, W., Wells, M., Beer, C. and Rossini, F. 1989. *Wasting Assets: Natural Resources in the National Income Accounts*. Washington D.C.: World Resources Institute.

Solow, R. M. 1986. On the Intertemporal Allocation of Natural Resources. *Scandanavian Journal of Economics*, 88:141-149.

United Nations. 1990. *SNA Handbook on Integrated Environmental and Economic Accounting; Preliminary Draft of Part 1, General Concepts*. New York: United Nations Statistical Office.

United Nations Development Programme 1992. *Human Development Report 1992*. New York:Oxford University Press.

Usher, D. 1980. *The Measurement of Economic Growth*. Oxford: Basil Blackwell.

Weitzman, M. L. 1976. On the Welfare Significance of National Product in a Dynamic Economy. *Quarterly Journal of Economics*, 90: 156-162.

Weitzman, M. L. 1991. On Diversity. Discussion Paper 1553, Harvard Institute of Economic Research. Cambridge: Havard University.

World Commission on Environment and Development 1987. *Our Common Future*. Oxford: Oxford University Press.

World Resources Institute, The World Conservation Union, United Nations Environment Programme 1992. *Highlights of the Global Biodiversity Strategy*.

Young, M. 1990. Natural Resource Accounting. In Common, M. and Dovers, S. (eds) *Moving Toward Global Sustainability: Policies and Implications for Australia*. Canberra: Centre for Continuing Education, Australian National University.

Zolotas, X. 1981. *Economic Growth and Declining Social Welfare*. New York: New York University Press.

1. Sustainability and sustainable development are related concepts. The latter was popularised by the Brundtland Report (World Commission on Environment and Development, 1987), according to which: "Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" (p 40). Common and Perrings (1992) note that economics and ecology have had rather different notions of sustainability, and propose a concept that embraces both.

2. Mäler notes Weitzman (1976) where the basic idea involved was established. See also Solow (1986), Hartwick (1990), and faber and Proops (1991).

3. Daly and Cobb (1989) give results for an Index of Sustainable Economic Welfare for the USA for 1950-1986. This is derived by a series of *ad hoc* adjustments to aggregate Consumption from the national income accounts. Common (1991) discusses this index and some anomalous features of its construction.

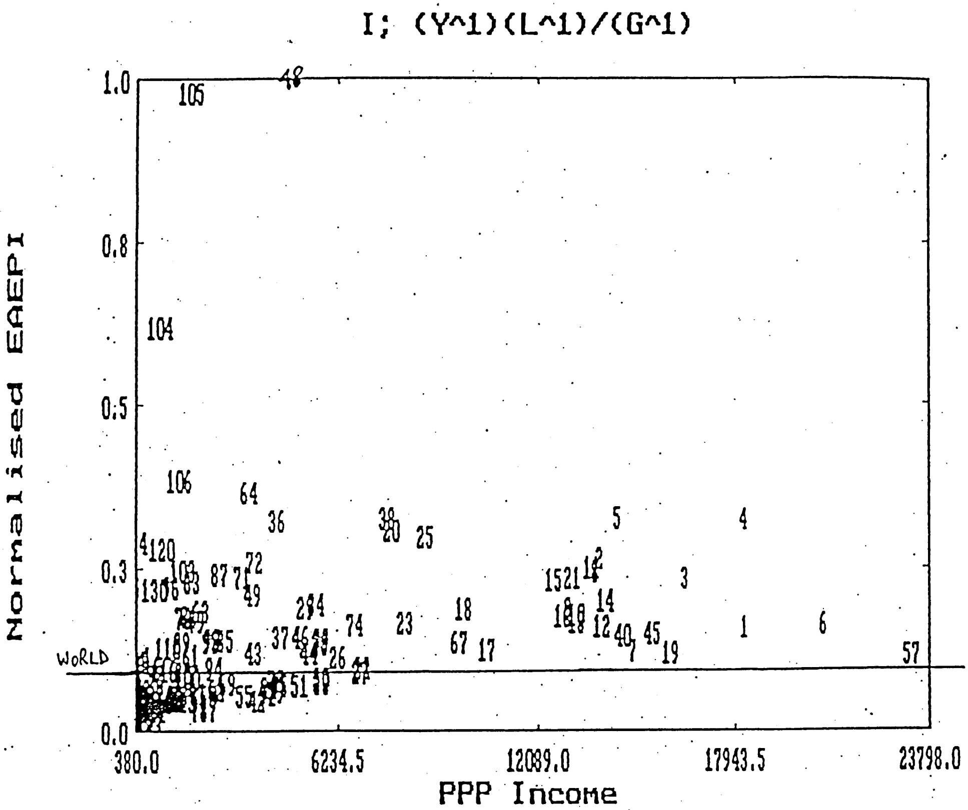
4. Kravis *et al* (1975) describe the basic methods by which conversions to PPP$s are made.

5. It is noted that the modelling basis for this takes no account of "opposing anthropogenic influences" so that "the net rate of increase in surface temperature is expected to be less, at least during the period for which sulphur emissions continue to increase, than would be expected from greenhouse forcing alone".

6. Houghton et al (1992) report the current state of knowledge regarding the sources and sinks for greenhouse gases.

7. Common and Salma (1992) discuss this in the context of (gross) Australian carbon dioxide emissions, and estimate that the emissions attributable to production for export are approximately equal to those arising overseas in the production of Australian imports. However, Australia exports coal which when burned overseas gives rise to carbon dioxide emissions which are approximately 60% of emissions arising in Australia. It should also be noted that Australia is an exporter of uranium.

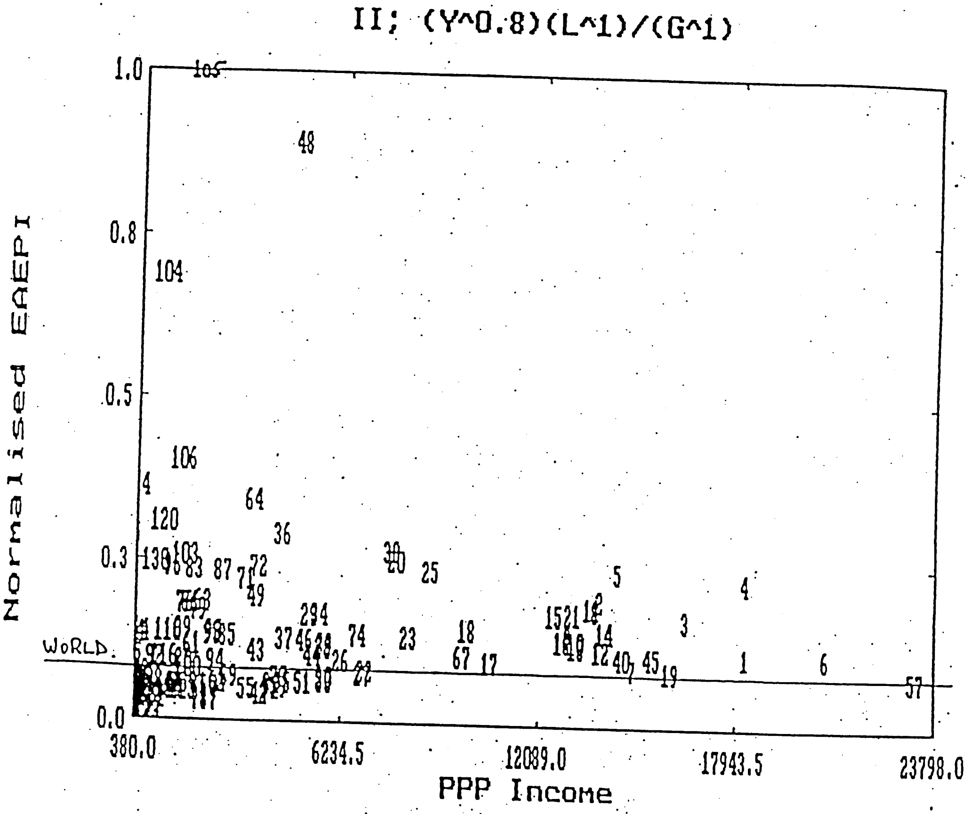
FIGURE 1.



I.

	Mean	Standard Deviation
High HD	0.173	0.076
Medium HD	0.149	0.164
Low HD	0.106	0.162

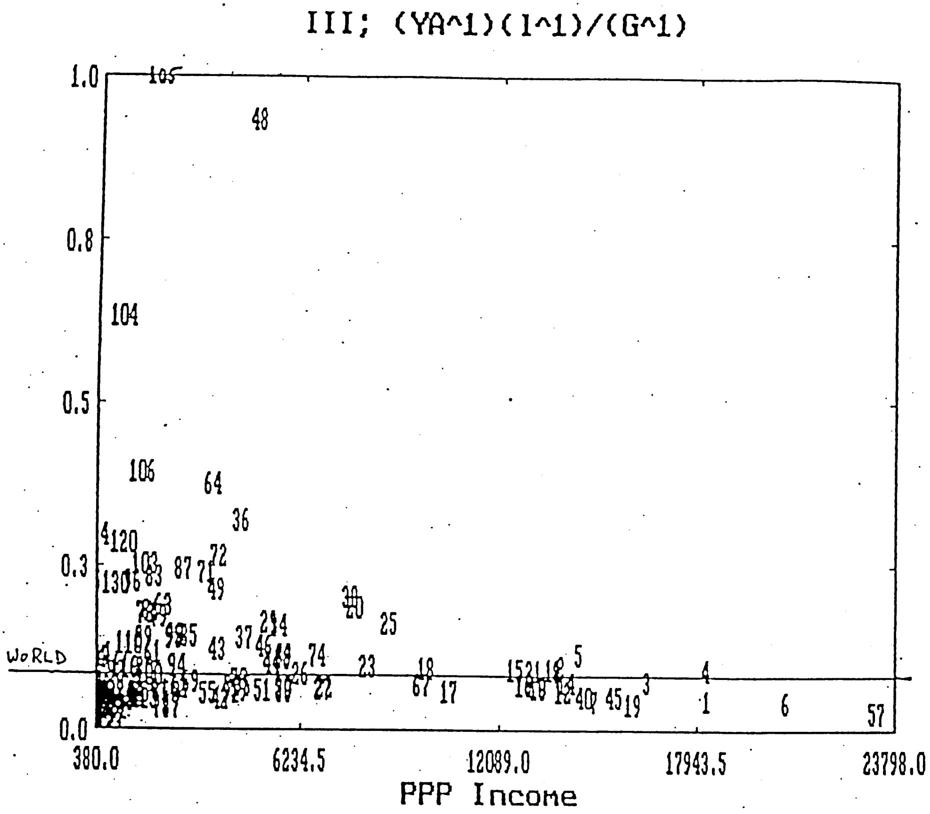
FIGURE 2.



II

	Mean	Standard Deviation
High HD	0.135	0.058
Medium HD	0.142	0.147
Low HD	0.123	0.172

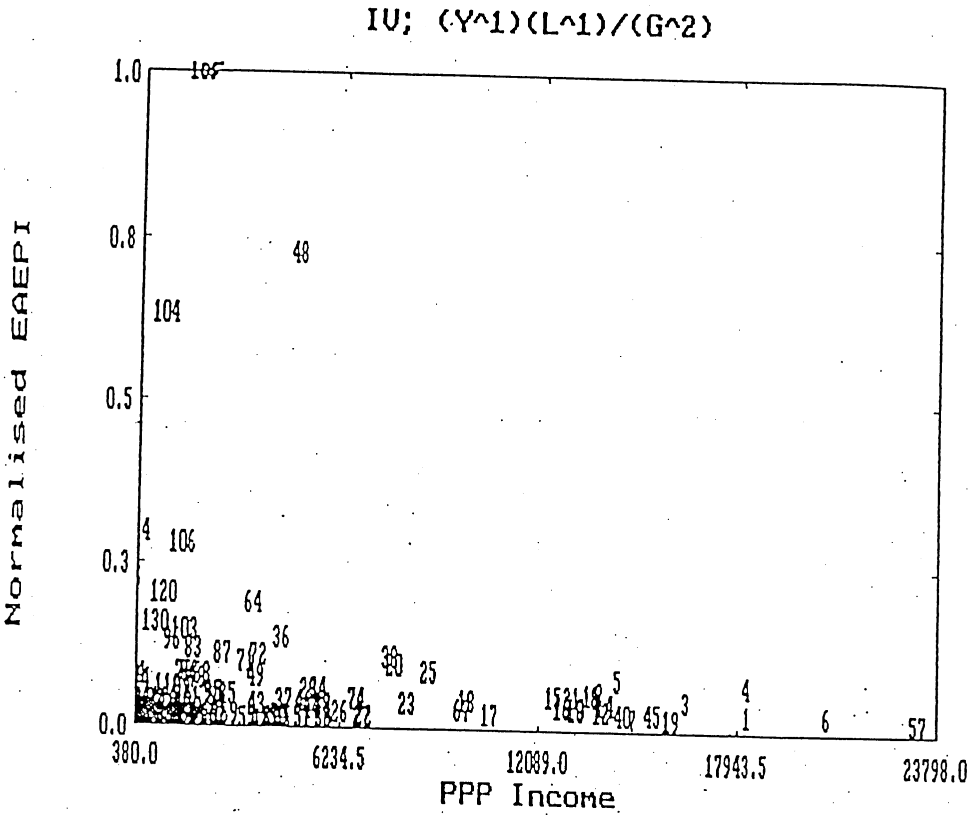
FIGURE 3.



III

	Mean	Standard Deviation
High HD	0.093	0.053
Medium HD	0.144	0.157
Low HD	0.108	0.166

FIGURE 4.



IV

	Mean	Standard Deviation
High HD	0.039	0.026
Medium HD	0.065	0.120
Low HD	0.080	0.165

EEEM working papers

9301 Perrings C. and Pearce D.W. Biodiversity conservation and sustainable development

9302 Halkos G. Optimal abatement of sulphur emissions in Europe

9303 Perrings C. Biotic diversity, sustainable development and natural capital

9304 Halkos G. Economic incentives for the implementation of optimal sulphur abatement strategies in Europe

9305 Halkos G. An evaluation of the cost of abatement under the main desulphurisation strategies

9306 Perrings C. and Walker B. Biodiversity loss and the economics of discontinuous change in semi-arid rangelands

9307 Common M. A cost effective environmentally adjusted performance indicator

The purpose of this series is to circulate current research by members of the Department of Environmental Economics and Environmental Management at the University of York.

Enquiries should be addressed to:

The Editor
EEEM Discussion Papers
Department of Environmental Economics and Environmental Management
University of York
York
YO1 5DD